Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
	)	
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183
	)	
	)	

COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its comments in response to the Commission's October 24, 2018, *Notice of Proposed Rulemaking* (NPRM) in the above-captioned dockets. In these comments, CORF addresses concerns regarding potential interference to protected passive scientific observations at 6-7 GHz. CORF recommends ways to protect these important observations.

I. The Role of Radio Astronomy and Earth Remote Sensing, and the Unique Vulnerability of Scientific Services to Interference.

CORF has a substantial interest in this proceeding, as it represents the interests of scientific users of the radio spectrum, including users of the Radio Astronomy Service (RAS) and Earth Exploration-Satellite Service (EESS) bands. These users perform

[1] See the Appendix for the membership of the Committee on Radio Frequencies.

extremely important, yet vulnerable, research.

A. Radio Astronomy

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The Nobel Prize winning discovery of pulsars by radio astronomers has led to the recognition of a widespread population of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than on Earth's surface. Subsequent radio observations of pulsars have revolutionized understanding of the physics of neutron stars and have resulted in the first experimental evidence for gravitational radiation, which was recognized with the awarding of another Nobel Prize. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in the Milky Way galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the Milky Way, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. The enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers have led to the recognition that most galaxies, including our own Milky Way, contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinarily high angular resolution, far superior to that which can be

obtained using the largest optical telescopes on the ground or in space.

The critical scientific research undertaken by RAS observers, however, cannot be performed without access to interference-free bands. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than 1 percent of one-billionth of one-billionth of a watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those human-made emissions are weak and distant.

B. Earth Remote Sensing—EESS

The Commission has also long recognized that satellite-based Earth remote sensing, including sensing by users of the microwave EESS bands, is a critical and uniquely valuable resource for monitoring the Earth and its environment. Satellite-based microwave remote sensing presents a global perspective and, in many cases, is the only practical method of obtaining atmospheric and surface data for the entire planet, particularly when optical remote sensing is blocked by clouds or attenuated by water vapor. Instruments operating in the EESS bands provide data that are important to human welfare and security and provide critical information for scientific research, commercial endeavors, and government operations in areas such as defense, security, meteorology, atmospheric chemistry, climatology, and oceanography. Examples are measurement of parameters—such as ocean surface temperature, wind velocity,

salinity, sea surface elevation, significant wave height, snowfall, and precipitation rate over the ocean—needed to understand ocean circulation and the associated global redistribution of heat. They also include monitoring soil moisture, a parameter needed for agriculture, flood, and drought assessment; for weather prediction (heat exchange with the atmosphere); and for defense (planning military deployment, assessing trafficability, and surveillance, among many other applications). Passive microwave sensors are also used to provide temperature and humidity profiles of the atmosphere critical for weather forecasting, information to monitor changes in polar sea and land ice cover in the persistently cloudy polar regions, and direct measurements useful in assessing hazards such as hurricanes, wildfires, and drought. Users of these data include the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense (DOD), the U.S. Department of Agriculture (USDA), the U.S. Geological Survey (USGS), the U.S. Agency for International Development (USAID), the Federal Emergency Management Agency (FEMA), and the U.S. Forest Service (USFS). Most of these data sets are also available free to anyone anywhere in the world.

Passive instruments in space are particularly vulnerable to human-made emissions because they rely on very weak signals emitted naturally from the Earth's surface and atmosphere. This is especially a concern for EESS because sensors in space monitor globally and view large swaths of the surface at one time. In this sense, the issue for EESS differs from that of RAS, which generally involves receivers at fixed locations that often can be protected with regionally specific restrictions.

II. Protection of Scientific Observations at 6-7 GHz.

A. Radio Astronomy

The NPRM states (at para. 20) that the proposed regulations "are designed to protect important incumbent licensed services that operate ... in various sub-bands of this spectrum." The RAS is an important and protected incumbent in the U-NII-7 sub-band. The 6650-6675.2 MHz band is important to the RAS for observation of methanol, which plays a significant role in research into star formation. The spectral line at 6668.518 MHz is among the spectral lines of greatest observational importance to RAS. See *ITU Handbook on Radio Astronomy* (ITU Radiocommunications Bureau, 2013) at Table 3.2.[2] This band is protected by Footnote US342, which states that "all practicable steps shall be taken to protect the radio astronomy service from harmful interference" in this band.

While this sub-band already has incumbent fixed operations, transmissions by unlicensed devices into protected RAS bands can be particularly harmful because, due to their mobility and lack of licensing records, it is very difficult to identify interference from such devices, to identify the operator of such devices, and to remedy the interference.

Accordingly, the Commission should include the locations of certain RAS observatories in its proposed Automated Frequency Control (AFC) regime, and AFC should be set up to require unlicensed devices to avoid transmission between 6650.0

[2] *See also* Recommendation ITU-R RA.314-10, Table 1.

and 6675.2 MHz within a certain radius of those observatories. In most instances, the horizon distance (D = 4.12*[sqrt(H_{tx})+sqrt(H_{rx})]), where D is in kilometers and the heights of the transmitter and receiver are in meters) provides an appropriate exclusion zone. Currently, RAS sites in the United States that operate at 6-7 GHz include the Arecibo Observatory, the Green Bank Observatory, the Very Large Array (VLA), the 10 stations of the Very Long Baseline Array (VLBA), the Owens Valley Radio Observatory, and the Allen Telescope Array. Exclusion zones listed in US385 should be adopted for protection of these RAS sites. RAS sites listed in the AFC system should be coordinated through the NSF Spectrum Management Unit (esm@nsf.gov).

In paragraph 53 of the NPRM, the Commission requests comments on whether client devices should be allowed to transmit probe requests, consistent with 802.11 standard, as a means for joining a network prior to receiving a frequency assignment. Due to the sensitivity of radio astronomy receivers and the faint signals emitted by astronomical sources, even low power use near a radio observatory has the potential to introduce harmful radio interference into astronomical observations. For example, an extrapolation of the ITU-R RA.769 (Table 2) levels of harmful interference for spectral line observations is -228 dB (W/(m^2 Hz)) at 6.65 GHz. Thus, even at the power limits proposed for client devices (see para. 78) and a best attenuation estimate from clutter models (para. 70), free space loss alone is not sufficient to provide protection to radio astronomy facilities. Thus, CORF recommends that U-NII-7 client devices use a passive probing process to connect to the standard power access point in order to prevent transmission in the 6650-6675.2 MHz band near a radio astronomy site.

In paragraph 73 of the NPRM, the Commission requests comments on the use of indoor low-power access points in the U-NII-5 and U-NII-7 bands under the same conditions as proposed for the U-NII-6 and U-NII-8 bands. As noted above, due to the sensitivity of radio astronomy receivers and the faint signals emitted by astronomical sources, even low power use near a radio observatory has the potential to introduce harmful radio interference into astronomical observations. Thus, CORF recommends that all U-NII-7 band devices be required to use the AFC system to identify exclusion zones, regardless of their power limit.

In paragraph 79 of the NPRM, the Commission seeks comment on whether higher power operations could be permitted in rural and underserved areas under certain conditions. However, when considering deployment of higher power devices, it is important to note that radio astronomy observatories are generally sited in rural areas, in order to take advantage of the reduced radio frequency interference (RFI) environment in those areas. Thus, in the geographic exclusion zones near the RAS sites listed above, unlicensed devices should be prohibited from transmitting between 6650-6675.2 MHz at any power level.

Last, as the Commission knows, aeronautical transmissions are particularly troublesome sources of interference to radio astronomy. Accordingly, CORF supports proposed Sections 15.407(d)(1) and (2) of the rules, which would prohibit use of the 6.525-6.875 MHz sub-band in aircraft or for communications from unmanned aircraft systems.[3] This proposed prohibition is critical to the protection of RAS observations.

[3] Footnote 5.458A states that "[i]n making assignments in the band 6700-7075 MHz to space stations of the fixed-satellite service, administrations are urged to take all practicable steps to protect spectral line observations of the radio astronomy service in the band 6650-6675.2 MHz from harmful interference from

B. Remote Sensing

Among the primary concerns for remote sensing in this proceeding are EESS bands near 7 GHz (6425-7075 MHz and 7075-7250 MHz). These bands are used for a number of EESS applications including observations of soil moisture, ocean surface wind speed, sea surface temperature, sea surface height, sea ice, snow, and precipitation. Measurement of these geophysical parameters is critically important for weather prediction, climate monitoring, and understanding changes in the global water cycle. For example, the Advanced Microwave Scanning Radiometer 2 (ASMR2) on the Global Change Observation Mission-Water (GCOM-W) satellite carries a radiometer measuring in a bandwidth of 350 MHz centered at 6.925 GHz, and the Navy's WindSat radiometer measures in a bandwidth of 130 MHz centered at 6.8 GHz. As a result of the microwave physics, this frequency range is optimal for measuring sea surface temperature and has been used for measuring soil moisture.

Footnote 5.458 provides that "in the band 6425-7075 MHz, passive microwave sensor measurements are carried out over the oceans. In the band 7075-7250 MHz, passive microwave sensor measurements are carried out. Administrations should bear in mind the needs of the Earth exploration-satellite (passive) and space research (passive) services in their future planning of the bands 6425-7025 MHz and 7075-7250 MHz." The Commission should carefully consider its rules in this proceeding so that use by EESS is preserved. For example, proposed Section 15.407(d)(3) would

unwanted emissions." While this footnote is intended to protect RAS observatories from satellite space stations, the concern is the same for other aeronautical uses.

provide some protection for remote sensing by limiting transmissions at 6.425-6.525 and 6.875-7.125 GHz to indoor locations, and CORF supports enactment of that rule section. In connection with Footnote 5.458's recommendation to protect important remote sensing of oceans in this band, the Commission should also modify proposed Section 15.407(d)(1) to include a prohibition on using the frequencies listed therein in ships. Thus, the text would be modified to state: "Operation of access points in the 5.925-6.425 GHz, 6.425-6.525 GHz, 6.525-6.875 GHz, and 6.875-7.125 GHz bands is prohibited in moving vehicles such as cars, trains, aircraft, *boats, and ships*."[4]

III. Conclusion.

CORF generally supports the sharing and flexible use of frequency allocations where practical, but protection of scientific observations, as discussed herein, must be addressed.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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[4] Alternatively, the rule section could be modified to state: "Operation of access points in the 5.925-6.425 GHz, 6.425-6.525 GHz, 6.525-6.875 GHz, and 6.875-7.125 GHz bands is prohibited in moving vehicles such as cars, trains, and aircraft*; and operation of access points in the 6.425-6.525 GHz, 6.525-6.875 GHz, and 6.875-7.125 GHz bands is prohibited in boats and ships.*"

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Appendix

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